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DECISION SUPPORT RENDERING TOOLS (DSRTs) FOR BATTLESPACE COMMAND AND CONTROL

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13. ABSTRACT (*Maximum 200 words*)

The overall goal of the Decision Support Rendering Tools (DSRTs) for Battlespace Command and Control Phase I effort was to demonstrate the technical feasibility of using DSRT technology to improve the commander's ability to maintain battlefield situational awareness. This report summarizes results of this project's Phase I work which occurred during the 29 November 1997 to 29 May 1998 time period. This project addressed U.S. Army Communications-Electronics Command's (CECOM's) Small Business Innovation Research (SBIR) Topic A97-054 of U.S. Department of Defense solicitation 97-02. Dual Incorporated integrated selected displays into CECOM's Battlefield Planning and Visualization for Windows NT (WinBPV) and developed other DSRT displays and 3D visualization functionality using 3D rapid prototyping tools. These rapidly prototyped displays included a 2D/3D composite intervisibility surface, a 3D unit status information object and a synchronization array heads up display. The proposed recommended design for a Phase II DSRT Synchronization Visualizer prototype is described. This report shows that the development and integration of 3D and 2D decision support rendering tools (DSRTs) for battlefield visualization is feasible, has Army user interest at both the lower and higher command echelons and shows indications of improving the commander's ability to quickly grasp the battlefield image.

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A. INTRODUCTION

The overall goal of this project's Phase I effort was to demonstrate the technical feasibility of using decision support rendering tool (DSRT) technology to improve the commander's ability to maintain battlefield situational awareness. This section summarizes results of this project's Phase I work which occurred during the 29 November 1997 to 29 May 1998 time period. This project addressed U.S. Army Communications-Electronics Command's (CECOM's) Small Business Innovation Research (SBIR) Topic A97-054 of U.S. Department of Defense solicitation 97-02. DUAL integrated selected displays into CECOM's Battlefield Planning and Visualization for Windows NT (WinBPV) and developed other DSRT displays and 3D visualization functionality using 3D rapid prototyping tools. This report shows that the development and integration of 3D and 2D decision support rendering tools (DSRTs) is feasible, has Army user interest at both the lower and higher command echelons and shows indications of improving the commander's ability to quickly grasp the battlefield image.

Most current generation battlefield visualization prototypes, including CECOM's Battlefield Planning and Visualization (BPV) System, feature standard 2D graphical user interfaces (GUIs) and focus on 2D displays to portray mission information relevant to the battlefield situation. There are perceptual and cognitive user interface problems associated with this current focus on 2D interfaces for battlefield visualization. Typically, a topographic view of the battlespace is separate from multiple related windows filled with text and numeric mission data. This can quickly create dense visual clutter on the system's display which hinders the user's ability to quickly detect and process critical mission information. Abstract mission information contained in 2D synchronization planning and execution matrices are portrayed separately from 2D or 3D topographic battlespace views, which requires the user to mentally integrate battlefield information across separate displays. The continued use of 2D GUIs with increasingly complex battlefield information has created systems which put a heavy cognitive load on the user interface. Problems with 2D GUI widgets include the use of menu hierarchies and multiple dialog boxes, which require many steps to accomplish visualization tasks.

In order to address the above problem area, DUAL has applied scientifically-based 3D graphical information visualization technology to the domain of battlefield visualization. This has resulted in rapidly prototyped Decision Support Rendering Tools (DSRTs) being demonstrated and limited integration of these displays in CECOM's BPV prototype system. DSRTs are 3D information tools which have a scientific basis in perceptual and graphical information processing theory and experimentation. The software architecture of DSRTs is based on the intuitive integration of realistic and abstract complex system information. Characteristics of the system which define it as being decision support rendering technology include: integrated 3D visualizations combining realistic and intuitive renderings of battlespace information; a taxonomy of DSRT battlespace classes; dynamic mapping of battlespace data to DSRT rendering attributes; direct 3D interaction with battlespace information; an ability to adjust and explore various levels of information detail, playback of battlespace events, and code developed based on the OpenGL graphics library. Current and anticipated results of this Phase I effort are assessments of the technical feasibility of battlespace DSRTs via feasibility demonstrations and technical reports, including recommendations for a Phase II prototype system.

In order to assess the feasibility of the DSRT approach for battlefield visualization, the following technical questions were addressed in Phase I: What are the specific information needs in current battlefield planning, rehearsal, and execution which can be met through DSRT data

filtering, tactical performance algorithms, and 3D rendered information display solutions? Has a full range of innovative algorithms and technologies been considered for application to DSRT battlefield visualization? How can dynamic DSRT renderings be most effectively registered with terrain elevation and other static battlespace data? What levels of DSRT detail are necessary for selected echelon command levels? Can multiple DSRT system features be integrated with an acceptable level of performance? Can overall DSRT system feasibility be demonstrated? Phase I specific technical objectives are based on the need to address the above feasibility issues and derive a design architecture for potential Phase II DSRT prototype implementation. Below is the list of the specific technical objectives which are being used to address Phase I feasibility issues:

- Conduct a needs assessment of current battlefield command and control tools and a DSRT testbed technology assessment
- Tailor and investigate the technical feasibility of a selected set of proposed DSRT visualization classes for battlespace visualization
- Investigate the use and integration of multiple DSRT system features
- Demonstrate the overall system feasibility for DSRTs
- Prepare Phase I report and recommend the design for a Phase II DSRT system prototype

In carrying out these technical objectives, our goal in Phase I was to demonstrate the feasibility of an innovative system of advanced 3D decision support battlespace rendering techniques which combine graphics and imagery to enhance battlespace awareness and data comprehension. This will allow more intuitive understanding and certainty in a commander's mental image of the battlespace. After this groundwork, development of DSRT prototypes can occur in Phase II, where feasible Phase I techniques are implemented as a library of reusable DSRT functions. This software is then fully integrated into CECOM's BPV prototype, further tailored and experimentally assessed by BPV customers. The following describes significant activities which occurred in this Phase I effort.

The Phase I contract was awarded to Dual Incorporated (DUAL) on 29 Nov 97. Further negotiation on contract payment and timing issues was conducted in discussions with CECOM personnel in early Dec 97 to ensure milestone payments and extending the contract to 29 May 98 to ensure that the Phase I effort was for a full six month period. Both these matters were successfully resolved. DUAL personnel involved in this project include Mr. Henry C. (Hank) Okraski, Senior V.P Research and Technology, Dr. David A. Dryer, Principal Investigator (PI), and Olatokunbo Toye (Ola) Fakinlede, Software Engineer.

The time spent during the Phase I period involved the following tasks: (a) Task 1 - Phase I Initiation (b) Task 2 - Needs and Technology Assessment (c) Task 3 - Tailor and investigate DSRT classes (d) Task 4 - Investigate use of multiple DSRT classes (d) Task 5 - Demonstrate overall system feasibility and (e) Task 6 - Phase I coordination and reports. A description of progress on each of these tasks during the report period follows.

A kickoff meeting for the DSRT project was held at CECOM in Dec 97. Participants included CECOM C2SID personnel involved with oversight of the DSRT project and the BC2 ATD. During this meeting relevant battlefield visualization technology issues were discussed; the overall DSRT concept, Phase I approach and schedule were presented and refined with CECOM feedback; and a demonstration of CECOM's BPV prototype software was given. As a result of this meeting, software development tool requirements for DSRT prototyping were refined and coordination was made to install WinBPV source code at DUAL for DSRT

development and integration. Also, CECOM provided DUAL with points of contact at Ft. Hood, TX and Ft. Benning, GA for use in needs assessment activities.

B. NEEDS AND TECHNOLOGY ASSESSMENT

DUAL has conducted a needs assessment of current battlespace command and control tools and procedures relevant to battlefield visualization. This assessment was conducted by reviewing existing literature from doctrinal and subject matter expert sources and conducting verbal interviews. Dialog was conducted with tactical and visualization experts at locations including Ft. Hood, TX, Ft. Monmouth, NJ, Ft. Benning, GA, Ft. Leavenworth, KS, and Ft. Knox, KY. This assessment highlighted weaknesses and strengths in current command and control visualizations and interfaces, as well as desired data requirements, measures, and other features. The result of this task is a comprehensive information source of relevant literature, interviews, and analysis to be used in refining and prioritizing specific areas where DSRT technology can be applied to battlespace visualization.

Task 2.1 - Literature Review

Information visualization literature was applied to battlefield visualization and input was provided to CECOM for incorporation in a white paper concerning the future of battlefield visualization. This submission is included as Appendix A. Many heuristics have been developed for information visualization, especially concerning 2D statistical graphics. These include Edward Tufte's "data-ink ratio", which advocates maximizing the amount of data represented per dot/pixel of ink. However, other experts caution that graphics impact and ease of detecting critical data are also important issues in information graphics design. Experimentally validated heuristics for 2D quantitative graphics include Cleveland's hierarchy which compared various statistical graphics, including pie charts, bar charts, and colors, for representing quantitative data. Based on perceptual theory and experimentation, length magnitudes in bar charts were significantly better. Unfortunately, despite the promise of 3D displays in theory, little experimentation has been done on the effectiveness of 3D quantitative graphics. In any situation where multiple system variables have to be understood, the use of emergent graphical display features, such as curvature, gap, and fundamental shape changes has shown promise in perceptual and some graphical experimentation. This use of emergent features was a focus of 3D graphics experimentation by the principal investigator and such features are being incorporated, where appropriate, in 3D DSRT display designs.

Another area of literature review concerned current military tactical mission graphics and doctrinal concepts which support such graphics. FM101-5-1, Operational Terms and Graphics contains familiar methods of displaying task organization status information include bar charts and gumball charts. A limited graphical notation is also defined for portraying mission type and status on 2D unit symbology. Current U.S. Army doctrine highlights the concept of *Combinations* for combined arms synergy, including complementary, reinforcing, and asymmetric effects. DSRT surfaces and volumes, such as the composite intervisibility surface, are a way of visualizing such doctrinal performance.

Task 2.2 - Battle Command Battle Lab (BCBL) Assessment

On 2-3 February 1998, the PI traveled to the U.S. Army Combined Arms Center (CAC) at Ft. Leavenworth, KS to conduct coordination and needs assessment activities. Activities included attending an In Progress Review (IPR) of a Phase II SBIR, entitled Course of Action Display and

Evaluation Tool (CADET) which also is sponsored by CECOM. In addition, the PI briefed and received feedback from COL Reed, Deputy Director, Battle Command Battle Laboratory (BCBL), Dr. Rebbapragada, DSRT Project Contracting Officer Technical Representative (COTR) and Richard Brown, Telecommunication Manager, Battle Command Proponency Division on the DSRT project. The trip was successful with COL Reed and Dick Brown endorsing the overall concept behind DSRTs, coordination being initiated with the Mounted Battle Lab, Ft. Knox, KY, and feedback received as part of the DSRT needs assessment.

The following lists assessment activities and significant comments made during those activities.

CADET IPR - Carnegie Group, Inc. 2 Feb 98

During the informal discussion period preceding the IPR, Dr. Rebbapragada asked the two companies conducting Phase I SBIRs relating to the Battlefield Planning and Visualization (BPV) project (DUAL included) to give a brief description of their projects. This briefing was received favorably by attendees, including MAJ GEN (Ret) Bruce Moore, Carnegie Group, Inc. stating that the Carnegie Group, Inc. and DUAL should dialog as their respective projects develop. Other significant comments by COL Reed follow:

- COL Reed mentioned the benefit of using visualization tools to monitor fight execution. The goal is to have an object oriented application where units/weapon systems can be acted upon by weather, etc.
- There is a Windows version of the Synch Matrix being developed by Carol Workman at CECOM as part of Maneuver Control System (MCS) Win.
- Course of Action (COA) tools are all text - what about incorporation of graphics?
- How to best graphically show unit attrition? Fuel consumption over time?
- COL Reed is interested in 3D objects and 3D Holographic displays for battlefield visualization.
- Applications need to have open architecture with "hooks" for interface/added functionality.
- DARPA is doing Command Post of the Future which needs to incorporate BPV-related projects.
- How can BPV-related applications be extended to Joint Operations?

Interview with Dick Brown, , Battle Command Proponency Division 3 Feb 98

As part of the DSRT needs assessment the PI interviewed Dick Brown, Telecommunication Manager, Battle Command Proponency Division. Mr. Brown is involved with the Army's Battlefield Visualization Concept and Master Plan. Significant interview comments from Mr. Brown follow:

- Automation has become part of the process in battlefield exercises and there is no longer a clear distinction between battlefield planning and execution.
- There is a current effort to produce a requirements document for a battlefield visualization display. EER and John Langston are under contract with CECOM to produce this document and it might make sense for DUAL to get involved or participate in this process.
- There is a requirement to visualize more pixels in Tactical Operations Centers. Is the solution larger displays or windowed user interfaces (or in the PI's view perhaps 3D user interfaces which provide more pixels through use of display depth and 3D display objects)?

Mr. Brown provided a recent briefing entitled "Display Devices for Digitized Forces" which was briefed to the Army Science Board. Also, he provided TRADOC Pam 525-70, Battlefield Visualization Concept and the Battlefield Visualization Master Plan (3rd Edition), Jan 98.

Correlation of Forces Method (COFM) meeting 3 Feb 98

Mark Curry, CECOM's BPV point of contact at Ft. Hood conducted a coordination meeting concerning the use of Correlation of Forces Method (COFM), which is basically the portrayal of force ratios in BPV. This meeting centered around the use of force ratios in U.S. Army Staff Training Drivers, such as CBS and the resolution and credible sources for such force ratio values. MAJ Florio (BCBL) and Mark Curry invited the PI's input, based on previous experience in U.S. Army combat modeling tools.

DSRT briefing to COL Reed, Command and Control Battle Lab 3 Feb 98

On 3 Feb, the PI was able to brief COL Reed, Deputy Director, BCBL on DUAL's DSRT Phase I effort with CECOM. The briefing was attended by COL Reed, BCBL; LTC Reck, BCBL; MAJ Florio, BCBL; and Dick Brown, Battle Command Proponency Division. COL Reed was enthusiastic about the DSRT concept and suggested that the Mounted Battle Lab at Ft. Knox with COL Gunzelman as Deputy Director be the logical "Green Suit" sponsor of the DSRT project, due to its battalion-level focus. Significant briefing comments from COL Reed follow:

- The functionality that DSRT is described is also important at the higher level of Corps and above.
- Ft. Hood is probably not the best venue to demonstrate DSRT in May 98. Perhaps a Battle Lab Deputy Directors Meeting would get more visibility. (Later on in discussions with LTC Reck Ft. Knox experiments in May/Jun 98 and Ft. Leavenworth Prairie Warrior in May 98 were also mentioned as good final demo opportunities).
- DSRT should also aid in tactical execution, not just planning.
- Commander's Critical Information Requirements (CCIR) in FM 101-5 and Mission, Enemy, Troops, Terrain, and Time/Space (METT-T) are good places to reference what information should be available to the commander.
- We need to address the cognitive processes involved in visualizing the battlefield.
- How to best use icons to represent units and unit dispersion. The PI mentioned previous work at Naval Postgraduate School which addressed this issue.
- Other research COL Reed thought was relevant includes Johns Hopkins Applied Physics (check w/ Al Poncini at CECOM); Navy Applied Situational Awareness (visualization of friendly/hostile).
- Icons representing aircraft have included actual aircraft representation, direction, altitude, and speed indicators.

This was a very productive visit to Ft. Leavenworth which contributed to the needs assessment phase of the DSRT Phase I project. Follow-on actions items included coordinating a trip to MBL at Ft. Knox and continued coordination with CECOM and BCBL.

Task 2.3 - Mounted Maneuver Battle Lab (MMBL) Assessment

On 19 March 1998, the PI traveled to the U.S. Army Armor Center at Ft. Knox, KY to conduct coordination and needs assessment activities. Activities included briefing and receiving feedback from COL Gunzelman, Deputy Director, Mounted Maneuver Battle Laboratory (MMBL), demonstration of the TRADOC Brigade and Below Virtual Battlefield (TB2VB) and demonstration of WinBPV. The trip was successful with COL Gunzelman endorsing the overall concept behind DSRTs, the potential identified for DSRT user evaluation during future MMBL experimentation, and feedback received as part of the DSRT needs assessment. The following are considered significant comments during the visit.

DSRT briefing to COL Gunzelman, Mounted Maneuver Battle Lab

COL Gunzelman feels that 3D high resolution terrain representation is extremely important at platoon to battalion level tactical command. MMBL is looking 20 years out and his view of the future is very short term tactical planning windows with commanders executing tactical maneuvers similar to a football quarterback calling audible plays from the line of scrimmage. This will be possible because of real time friendly unit information and much of the synchronization planning being automated. He did not think a focus on the synchronization matrix was appropriate at the lower echelons since this tool is not being widely used and would be to time consuming. He did like the idea of DSRT composite intervisibility surfaces and 3D unit symbols as tools to portray increased mission information in 3D terrain representations.

TRADOC Brigade and Below Virtual Battlefield (TB2VB) Demonstration

MAJ Burns, director of the TB2VB testbed then conducted a demonstration. The testbed currently uses 2D information displays and a 3D MODSAF stealth view. Plans are to use BPV's 3D view after it has met certain requirements for terrain representation. Displays are primarily created in-house and they include three color "gumball" status charts representing unit status and color-coding of displays to represent the aging of data. After initial hesitation about getting involved with DSRT displays due to upcoming requirements, MAJ Burns was very agreeable to assess any DSRT prototype displays which are part of the SGI BPV system. MAJ Spragg also identified the Concept Experimentation Program (CEP) resume sheet as a vehicle for additional MMBL work with DSRT displays.

WinBPV demonstration

Ron Saari conducted a WinBPV demonstration for MMBL personnel. Comments on improving the system related to simplifying the user interface (not so many inputs and windows) and enhancing unit status displays.

Task 2.4 - Other Needs Assessments

Discussions have also occurred with personnel involved in BPV development at Ft. Hood and Ft. Benning. Ft. Benning needs for Military Operations in Urban Terrain (MOUT) scenarios and visualization tools are being considered for DSRT displays. MOUT needs include visualizing METT-T parameters in multi-story buildings. Mark Curry, BPV representative at Ft. Hood, has dealt with BPV use at higher echelons, such as brigade and corps levels. The use of the interactive smart board at Ft. Hood appears to be a technology which could enhance DSRT interactions.

Task 2.5 - Technology Assessment

DUAL has conducted a technology assessment of potential components for DSRT prototype development. This technology assessment was directed towards hardware and software, which has enhanced the operational DUAL visualization testbed into a CECOM-compliant DSRT development system. Improved low cost OpenGL graphics acceleration and a cross platform OpenGL 3D software technology was investigated as part of this assessment. Sense8 WorldToolKit, Division dVS/dVISE (both currently installed at DUAL), as well as lower level OpenGL development tools, were evaluated concerning cross platform capability, integration with current CECOM BPV software, and ease of DSRT development. Both Sense8 and Division have high-level scripting and low-level C++ coding development interfaces for software creation.

As a result of the technology assessment, an Intergraph Windows NT development platform has been purchased and received by DUAL as the primary DSRT development platform. After talking to BPV personnel it appeared that the purchase of the terrain/imagery processing software, such as Erdas Imagine or Intergraph Geodex/Active Terrain was not necessary. Real-time 3D tools at DUAL - Sense8 WorldToolKit and Division dvReality were used as rapid prototyping tools of DSRT concepts. Win BPV source code has been provided to DUAL to develop limited enhancements and extensions using OpenGL and extend selected BPV functions. In order to run and extend Win BPV, Hummingbird's Exceed XDT for Windows NT and Visual C++ were purchased and received.

Even though this formal DSRT needs and technology assessment was completed early in Phase I, new technology information and user feedback continued to enhance DSRT development through Phase I completion.

C. FEASIBILITY INVESTIGATION OF BATTLESPACE DSRT SYSTEM FEATURES AND SYSTEM INTEGRATION

Task 3 - Tailor and investigate DSRT classes

DUAL has tailored and investigated the technical feasibility of a selected set of proposed DSRT visualization classes for battlefield visualization. Using the battalion level tactical missions as a start point, DSRT data requirements, desired levels and types of tactical performance measures, and desired user-data interactions have been extracted from the DSRT needs assessment. Through graphical storyboarding and limited display coding, 3D DSRT classes and GUI interfaces to support identified battlefield requirements were developed and presented to potential battle lab integrators. In particular, the DSRT composite line of sight surface and DSRT 3D unit symbols were requested by Ft. Knox to be incorporated into CECOM's BPV for upcoming MMBL experimentation. 3D dynamic information objects, data conversion tools, linked database structures, and user-data interaction tools developed under a NASA Small Business Innovation Research (SBIR) Phase II project were incorporated into this initial concept of DSRT displays and functionality. The integration of "gumball" status charts on DSRT 3D dynamic information objects was also investigated and integration is currently occurring as part of Task 4 - Investigate Use of Multiple DSRT Classes. In addition, DSRT surface and volume classes were enhanced and investigated through storyboarding and tailoring existing code to produce initial functionality. including mapping of DSRT surface output data to color scales and dynamic manipulation of this data color mapping. Rendering techniques including opacity and visibility effects were analyzed as potential rendering solutions for DSRT information portrayal on a 3D terrain database. Techniques for rendering mission control graphics on photorealistic textured 3D terrain were also assessed.

Task 4 - Investigate Use of Multiple DSRT Classes

DUAL is currently investigating the technical feasibility of integrating multiple DSRT system features from Task 3 into DSRT composite class displays and interfaces. This integration involves the ability for simultaneous portrayal and overlay of DSRT objects, surfaces, volumes, and GUI tools in a real-time 3D rendered environment. Selective integration of 3D dynamic

information objects, data conversion tools, linked database structures, and user-data interaction tools is implemented, tailored, and assessed for DSRT use in battlefield visualization. The focus of this investigation is to extend the 2D synchronization matrix into a 3D DSRT composite synchronization array. This investigation involves methods to limit the amount of sensory (e.g., visual) overload caused by simultaneous feature portrayal, methods to navigate, highlight, or selectively view features of immediate importance, and various technical solutions to achieve cost-effective real-time portrayal of multiple DSRT features as DSRT composites.

Task 4.1 - DSRT Composite Intervisibility Surface Integration

DSRT Composite Intervisibility surface functionality has been developed and initially integrated into the current version of WinBPV. Using digital terrain representation and enhancements to line of sight algorithms, a surface is calculated whose height at any point on the ground (over the area of interest) is given by the number of direct fire weapons which are able to destroy enemy armor at that point: the higher the surface at a given point, the greater is the massing of firepower at that point. As shown in Figures 1,2, & 3, this surface height can be assigned rendering attributes (e.g., color) according to its height and displayed directly on the terrain over map or photo imagery of the area. The changes in color over a given region reflect the changes in the massed firepower, for the given locations of friendly weapons systems considered. Such displays give snapshot pictures which are useful in portraying the synchronized massing (or lack of massing) of combat power of the force at a given point in time. More importantly, rendering such surfaces in realtime and running them sequentially, can give valuable indications of how the massing of the lines of sight changed during the battle, due to movement or attrition of the weapons portrayed. This display has been developed for both the 2D and 3D views of BPV. The 3D view, shown in Figure 3, gives the lower level commander the ability to assess composite unit combat potential from key terrain or a bird's eye aerial view. The color scale range boundaries can be interactively adjusted for these surfaces. For example, in Figures 2 and 3, only areas where 4 or 5 tanks have intervisibility are shown. In this way the user can eliminate visual clutter from the screen and just visualize areas of heavy intervisibility massing.

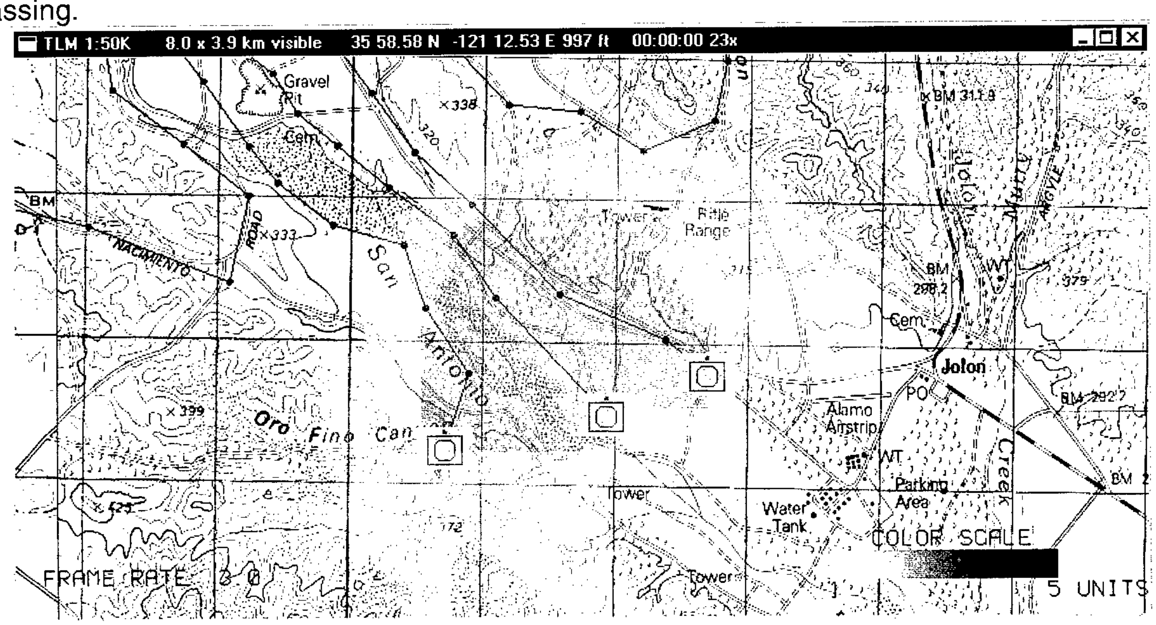

Figure 1. Dispersed 2D composite intervisibility surface of 5 tanks

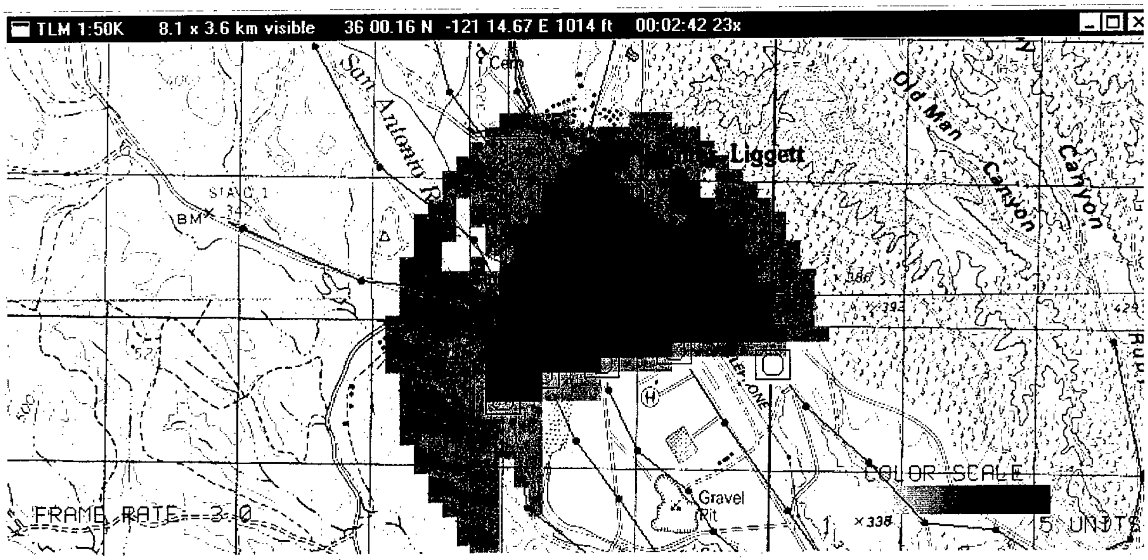

Figure 2. Concentrated 2D composite intervisibility surface of 5 tanks (only 4 and 5 values shown)

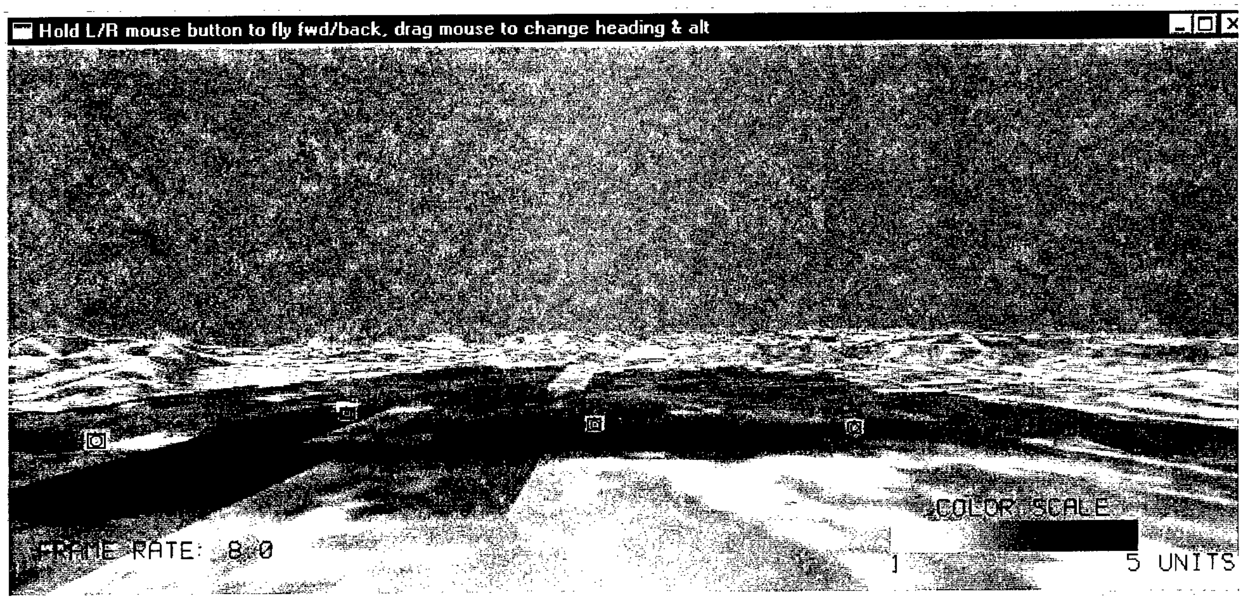

Figure 3. 3D composite intervisibility surface of 5 tanks (only 4 and 5 values shown)

Task 4.2 - DSRT Unit Object Integration

A DSRT object has also been prototyped using the Sense8 WorldToolKit 3D development environment. DSRT 3D objects portray levels of critical battlefield entities (including friendly and enemy forces) and mission control points (including contact, coordination, and decision points). Concerning battlefield entities, levels of echelon detail range from deaggregated individual weapons systems to aggregated units. Figure 4 shows an example rendering of a DSRT entity object representing an Army company. The icon at the top of the object represents

the overall unit composition and status using current symbology from FM 101-5-1. The sides can represent unit resource status, such as personnel, fuel, and ammunition. Through use of curvature, the status of unit resources versus planned usage is easily visualized, with curvature out meaning the unit is doing better than expected in that resource category. By viewing the resulting shape at the top of the unit, an overall unit resource status can be quickly derived. Objects will use a combination of transparency and rotation in 3-dimensional space so the user can get a view of all information displays.

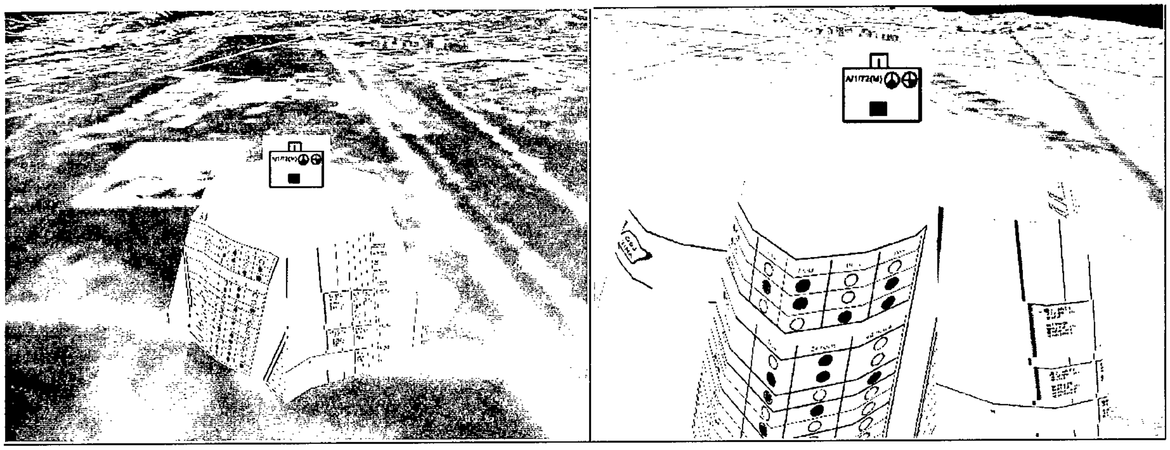

Figure 4. 3D DSRT unit symbology with nominal sides and using the curvature emergent feature

Task 4.3 - DSRT Composite Development

DSRT composites have been developed using various combinations of DSRT objects, surfaces, and volumes to portray comparisons and interactions between different battlefield entities, environmental factors, and control measures. A focus of DSR composite development is to extend the widely used 2D synchronization matrix into a 3D Synchronization Visualizer (Sync Visualizer). This Synch Visualizer will be portrayed as an array of intuitive renderings in the 3D environment consisting of DSR objects, surfaces, and volumes visually linked with temporal and spatial attributes. A Synch Visualizer rapid prototype was demonstrated during the Phase I final demonstration as described below.

D. FEASIBILITY DEMONSTRATION AND REPORTS

Task 5.1 - Initial Feasibility Demonstration - 13 Apr 98

An initial feasibility demonstration of DSRT composite intervisibility surface and DSRT unit object representation was conducted as part of an IPR at CECOM on 13 Apr 98. This demonstration showed DUAL's ability to rapidly prototype enhanced DSRT tools and to integrate DSRT tools into BPV prototype source code. The demonstration was well received by CECOM BPV personnel and resulted in a productive brainstorming session on applying DSRT concepts to the Synchronization Matrix.

Task 5.2 - Final Feasibility Demonstration - 20 May 98

On 19-20 May 1998, the PI traveled to the U.S. Army Communications-Electronics Command (CECOM) Ft. Monmouth, NJ to conduct a final demonstration of DUAL's Decision Support Rendering Tools (DSRTs) for Battlespace Command and Control Phase I SBIR project. This demonstration further addressed Phase I DSRT feasibility for battlefield visualization. The main activity was an In Progress Review (IPR) of a Phase II SBIR, entitled CADET which also sponsored by U.S. Army CECOM (CECOM). DUAL's demonstration and briefing focused on proposed concepts for developing a composite DSRT Sync Visualizer prototype in Phase II. This demonstration used relevant system features investigated in Tasks 3 and 4. This feasibility demonstration was conducted with CECOM personnel and potential system users to obtain feedback on demonstrated system features and DSRT prototype concepts.

The main highlight of this demonstration was the Synchronization Visualizer "heads-up display" shown in Figures 5-7, which allows temporal-based synchronization tasks to be superimposed and directly linked to mission information graphics portrayed on spatial terrain. The Sync Visualizer is shown as 3D tunnel array, which is integrated into the 3D battlespace environment. Battlefield operating system (BOS) categories are mapped to sides of the display and the time axis is slaved to the user's viewpoint direction. In effect, the user is viewing the 3D terrain through a transparent synchronization tunnel 'lens' which represents BOS categories and a continuous time axis. The user has the ability to slide the tunnel forward and backward to travel forward and backward in time along the Sync Visualizer array.

Sample unpopulated synchronization arrays have been rapidly prototyped in Phase I to demonstrate the feasibility of the Sync Visualizer interface concept. The left side of Figure 5 shows a nominal synchronization array with straight sides projected until end state, indicating expected mission performance. However, the right side of Figure 5 shows inward curvature in the maneuver and other BOSs indicating less than expected projected mission performance due to synchronization or other mission problems.

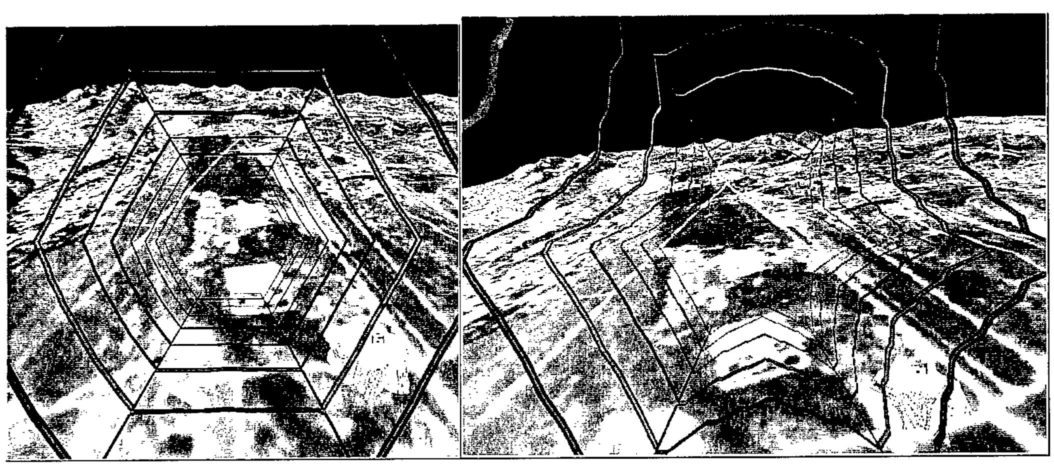

Figure 5. Rapid prototype unpopulated synchronization arrays with view of 3D battlespace

Another unpopulated synchronization array view in Figure 6 shows how at a critical point the Sync Visualizer can portray two or more courses of action which could result from different decisions during mission execution. If both synchronization array branches were fully

populated, the projected shape of resulting end states and interrelationships between entities provides valuable decision support information for that decision point.

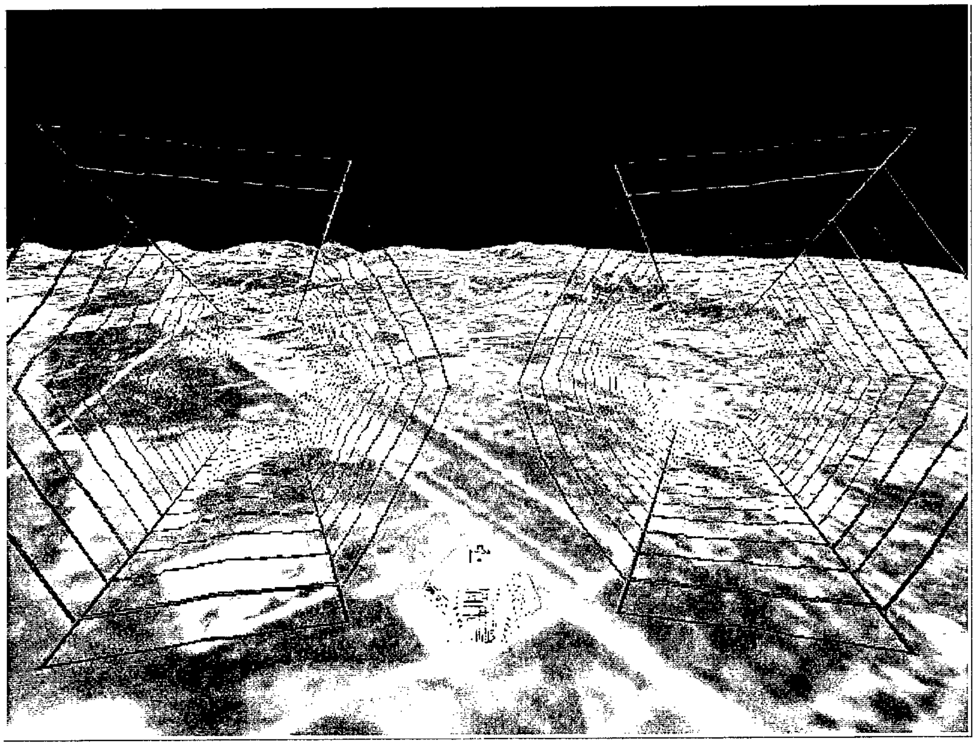

Figure 6. Rapid prototype unpopulated synchronization arrays showing two courses of action at a decision point

A populated synchronization array view is portrayed in Figure 7. The synchronization array is populated with mission task and graphics icons critical to mission accomplishment. Critical tasks including unit logistics, maneuver, combat support, and combat service support activities which are arrayed by BOS and time in order to ensure mission success. Also, critical observation points (OPs), targeted areas of interest (TAIs) and decision points (DPs) are portrayed which influence command decisions about the mission. The synchronization visualizer prototype concept is discussed in more detail below in Section F: Recommendations for Phase II DSRT system prototype design.

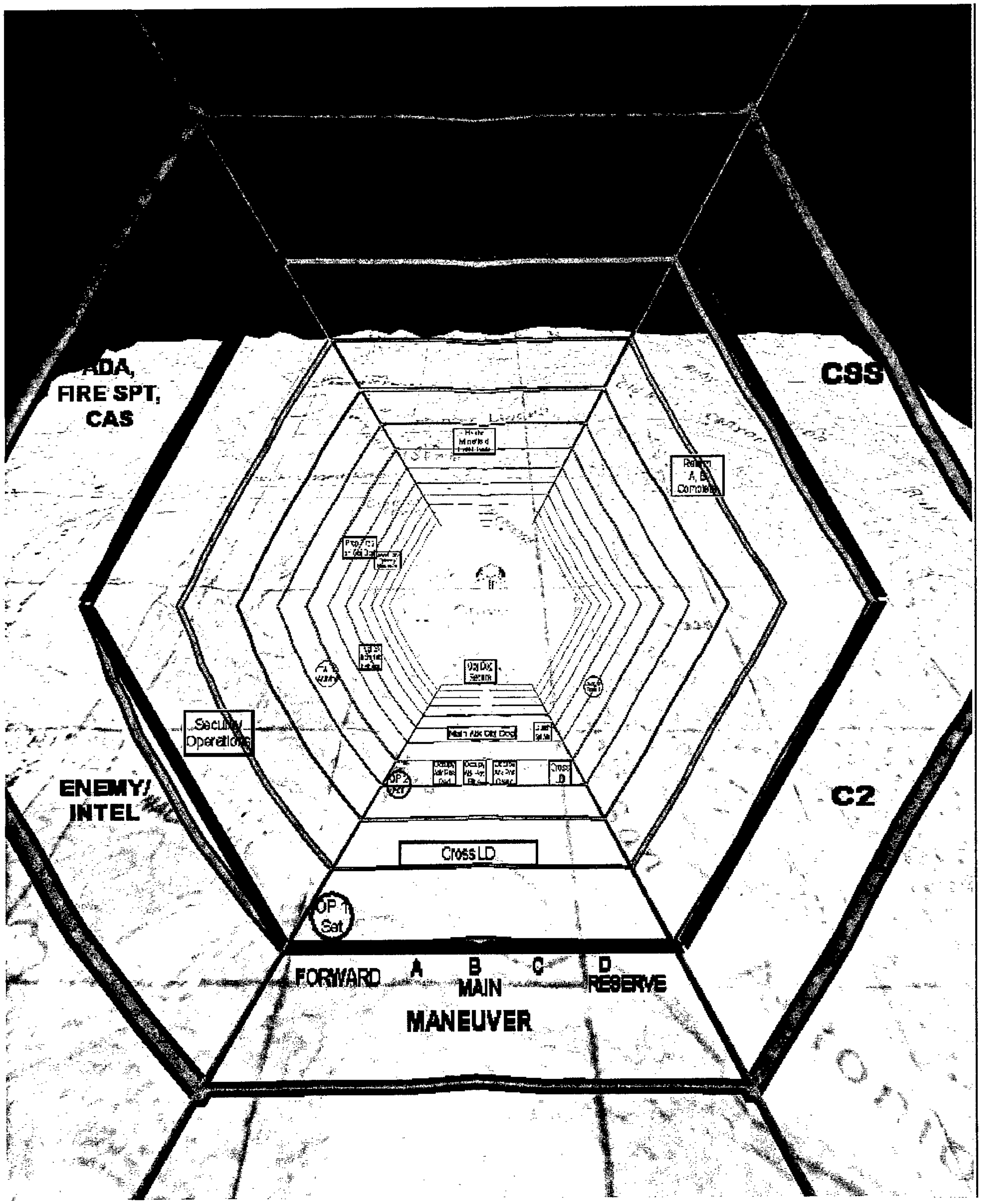

Figure 7. Rapid prototype populated synchronization array showing battalion attack activities

During the visit, MAJ John Frame, 4th ID G2 (Intelligence) section highlighted the need for

representation and interaction with Synchronization Matrix tasks. There are certain critical tasks where the planning staff would need to visualize in more detail the pre- and post- task dependencies and other task attributes. This could be done with DSRT task-based information objects similar in design to the demonstrated unit-based DSRT objects. Also, John Langston, EER/Carnegie Group asked if key personnel at Ft. Leavenworth had seen the Synchronization Visualizer interface and wanted to assist in showing it to these personnel. However, further demonstrations involving travel will probably depend on Phase II funding.

This was a very productive visit to Ft. Leavenworth which completed the required feasibility demonstration of the DSRT Phase I project. The trip was successful with the Contracting Officer Technical Representative (COTR) Dr. Lakshmi Rebbapragada having positive comments about the DSRT displays and the Synchronization Visualizer concepts demonstrated during the visit and presented in the invited Phase II proposal.

Task 6.1 - Phase I Interim Report

An interim Phase I report was prepared and submitted by DUAL to CECOM to assess Phase II potential of the DSRT project. This report was delivered as part of an in-progress review (IPR) at CECOM on 13 Apr 98.

Task 6.2 - Phase I Final Report

This report submission is DUAL's Phase I final report, including the needs and technology assessment, feasibility investigation of battlespace DSRT system features and integration, a description of the feasibility demonstration, and recommendations for a Phase II DSRT system prototype design. As stated in the original solicitation, language used to report Phase I progress in the already submitted Phase II proposal is used verbatim in this Phase I final report with changes to accommodate results after Phase II proposal submission and modifications required to integrate the final report into a self-contained, comprehensive, and logically structured document.

E. PHASE I CONCLUSIONS

As detailed above, the project's critical tasks were accomplished on schedule. This report and the Phase I demonstrations show that the development and integration of 3D and 2D decision support rendering tools (DSRTs) is feasible, has Army user interest at both the lower and higher command echelons and shows indications of improving the commander's ability to quickly grasp the battlefield image, as shown by intense interest in DSRT technology at U.S. Army Battle Labs. In particular, the Mounted Maneuver Battle Lab at Ft. Knox has expressed interest in doing experimentation using DSRT displays and has invited and received input from DUAL for a Concept Experimentation Program (CEP) resume, which is related to current and future DSRT development. This CEP resume, entitled Battlefield Virtual Information Tools for Brigade and Below (BVITB2), has made the first cut and is currently being evaluated at the TRADOC level. It is attached as Appendix B. MMBL personnel feel DSRT composite intervisibility surfaces and 3D unit status objects concepts have the potential to enhance the commander's battlespace awareness. Now, recommendations for a Phase II DSRT system prototype design will be presented.

F. RECOMMENDATIONS FOR PHASE II DSRT SYSTEM PROTOTYPE DESIGN

Phase II Technical Objectives and Approach.

Due to successful demonstration of Phase I DSRT techniques for battlespace visualization, DUAL has been invited to propose a Phase II effort to develop and assess a DSRT prototype focusing on synchronization planning and execution. This proposal was submitted on 14 May 98. Characteristics of the proposed prototype concept which define it as being decision support rendering technology include: integrated 3D visualizations combining realistic and intuitive renderings of battlespace information; a taxonomy of DSRT battlespace classes; dynamic mapping of battlespace data to DSRT rendering attributes; direct 3D interaction with battlespace information; an ability to adjust and explore various levels of information detail, playback of battlespace events, and code developed using the OpenGL graphics library.

In order to develop and assess a DSRT prototype, the following issues need to be addressed in Phase II: How can demonstrated algorithms and techniques be implemented as software tools and integrated as a system to fill identified battlespace synchronization needs? How can proposed DSRTs be most effectively embedded in the BPV development effort? What aspects of DSRT architecture should be applied to the overall BPV architecture? What is the experimentally assessed objective and subjective effectiveness of DSRTs for battlespace visualization?

Phase II specific technical objectives are based on the need to address the above implementation issues. Phase II tasks of this project include DSRT software development and testing, investigating technology enhancements, and user studies which result in an embedded and tested DSRT prototype in the BPV system. Below is a list of potential technical objectives to address Phase II issues:

1. Define prototype functionality requirements
2. Conduct system design engineering of the DSRT prototype
3. Conduct software engineering to develop DSRT components
4. Conduct software integration to embed DSRTs as a module in the BPV system
5. Conduct formal software testing
6. Conduct customer testing and evaluation
7. Refine prototype based on software and customer testing
8. Fully document the DSRT battlespace visualization prototype module
9. Demonstrate evolving Sync Visualizer releases

Based on Phase I design recommendations, DUAL develops an initial description of functional requirements for the DSRT prototype. This requirements description includes functionality descriptions of data conversion; data filtering; battlespace performance algorithms; rendering algorithms; database component structures; relational query capability; DSRT rendering objects, surfaces, volumes, statistical graphics; and overall system navigation and GUI interaction. DUAL then conducts systems and software engineering to translate the functional requirements description into an integrated software design consisting of interacting process modules. Also interface mechanisms are coded for input/output to other potential battlespace visualization software modules, including BPV database structures; automated planning tools;

and other planning, rehearsal, simulation, and visualization software tools. When appropriate, software modules are designed as generic application programming interfaces (APIs) which can be reused by other BPV software tools to enhance code reuse. DSRT database structures are designed with the goal of adopting data standards, when possible, for the larger set of BPV database structures.

After initial software engineering, DUAL and CECOM conduct software integration of the DSRT system as a linked module of library routines to meet the needs of the evolving BPV system. Where appropriate, this integration will involve standardizing of database structures and formats; APIs concerning battlespace performance algorithms, rendering algorithms, and data conversion and filtering; and GUI tools for a consist user interface. Interfaces will be developed or adopted to allow DSRT interaction with BPV database structures, automated planning tools, and other visualization software tools. Integration work will be conducted at DUAL's DSRT testbed and demonstrated for effectiveness at CECOM to ensure software compatibility.

At appropriate times selected by CECOM and TRADOC, AWEs or other demonstration exercises involve DSRT prototypes for evaluation and modification as necessary. DUAL also conducts limited studies on system users to assess its effectiveness. These evaluations involve creating new qualitative and quantitative measures for assessing the effectiveness of battlespace awareness and information comprehension. Integrated DSRT software and complete documentation are delivered to CECOM upon project completion.

Phase II Work Plan

The Phase II work plan is designed to continue the successful Phase I proof of concept of DSRTs through the development of a Sync Visualizer prototype and integration of this functionality in CECOM's BPV system.

Deliverables

The proposed project deliverables for Phase II are the following reports, software, and documentation:

- Monthly technical progress reports
- Six month and one year interim technical reports
- DSRT Sync Visualizer Release 2 software prototype
- Technical documentation for DSRT Sync Visualizer software prototype including installation guide, user's guide, and commented software code modules
- Final technical report including summary of project activities and Phase III follow-on government project and private sector commercialization plans

Overall DSRT Synchronization Visualizer Prototype Concept

DSRTs are innovative tools which portray critical battlespace information through recent, scientifically-based information visualization and interaction techniques. Based on Phase I feasibility demonstrations, these techniques show promise in addressing the urgent need for an effective synchronization planning and execution interface. The DSRT prototype concept to address this need is called the Sync Visualizer, which extends the currently used Synchronization Matrix (Sync Matrix) as shown in Figure 8. This figure shows the typical arrangement of a Sync Matrix with the Y axis for battlefield operating system (BOS) categories and the X axis for time. While the Sync Matrix is a separate 2D display, the Sync Visualizer is

shown as a 3D tunnel array, which is integrated into the 3D battlespace environment. BOS categories surround the user's viewpoint and the time axis is slaved to the user's viewpoint direction. In effect, the user is viewing the 3D terrain through a transparent synchronization tunnel 'lens' which represents BOS categories and a continuous time axis. The user has the ability to slide the tunnel forward and backward to travel forward and backward in time along the Sync Visualizer array. Links can be portrayed which connect icons in the synchronization array to DSRT object entities and surfaces in the 3D battlespace, thus directly linking temporal and spatial mission relationships.

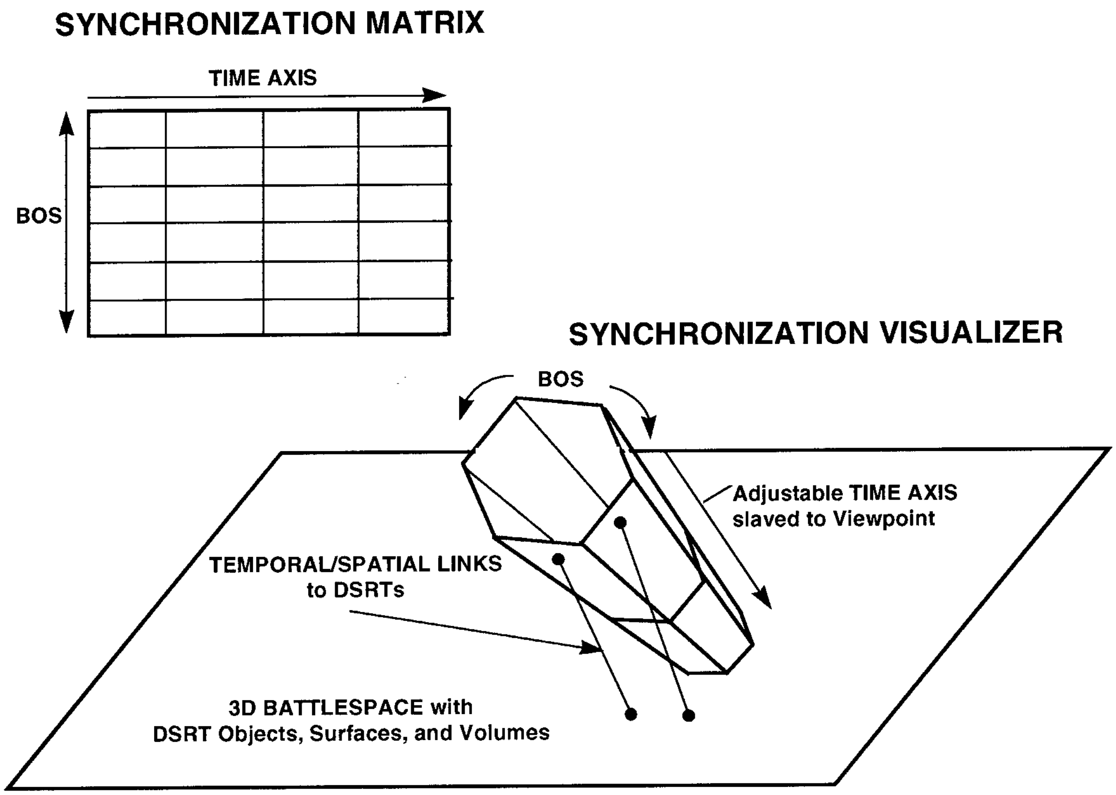

Figure 8. Extensions from synchronization matrix to synchronization visualizer

Figure 9 shows additional structure of the Sync Visualizer array. This figure looks down the 'barrel' of the array as a user would in 3D battlespace. However, an actual user would be positioned inside the array. BOS category labels are shown mapped to sides of the array. The orange hexagon shows the plane of the array tunnel which represents the mission's current state. The green hexagon represents the projected end state of the mission. In between these hexagon planes are sequential mission phases. The sides of the synchronization array are transparent except for grid markings so the user has a view of the 3D battlespace with its associated DSRT and mission symbology.

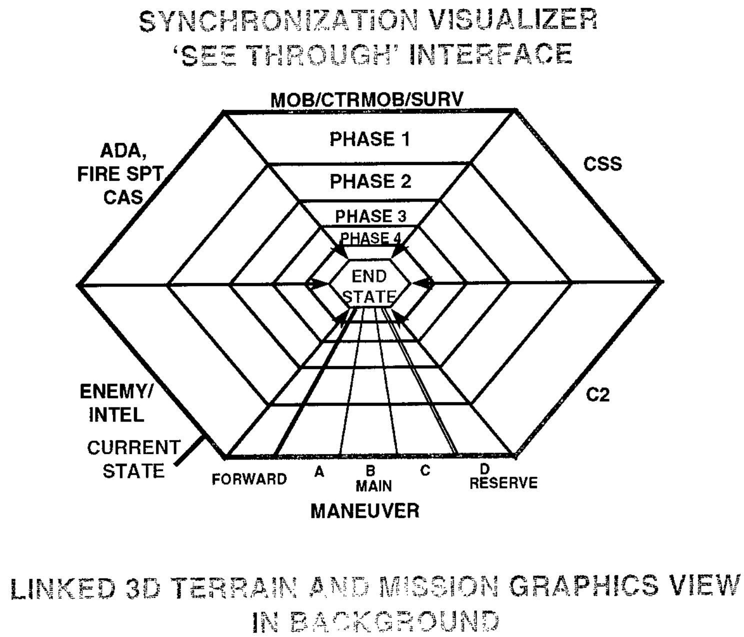

Figure 9. Synchronization Visualizer array framework

In Figure 10, the synchronization array is populated with mission task and graphics icons critical to mission accomplishment. A battalion attack mission is portrayed with critical tasks including unit logistics, maneuver, combat support, and combat service support activities which are arrayed by BOS and time in order to ensure mission success. Also, critical observation points (OPs), targeted areas of interest (TAIs) and decision points (DPs) are portrayed which influence command decisions about the mission. One example execution decision in this mission is the time and attack axis for launching the D Company reserve. Figure 11 shows the ability to display dependencies between tasks and other entities in the array through red arrow symbols. The commander can create and visualize such task dependencies during the planning process and then monitor the execution of these tasks to detect problems or opportunities caused by differences between planned and actual mission execution. The ability to link synchronization array icons to corresponding DSRTs in the 3D battlespace is then shown with the blue link lines in Figure 12. In this view, the 3D battlespace DSRTs are below the user's field of view so users would reorient their viewpoint to observe the spatial location of linked objects. Finally, in Figure 13, the curvature of BOS category sides changes depending on the current and projected status of the BOS at times during the mission. If the side is curved in, then that BOS category is not doing as well as planned. If the side is curved out, then the BOS category is doing better than planned. A straight side with no curvature indicates the BOS category is doing as expected. By mapping the 'emergent feature' of curvature to the synchronization array, the user can tell at a glance the overall current and projected mission status and also mission status by BOS. In Figure 13, the maneuver and C2 BOSs are projected to have unsatisfactory mission performance by the mission's end state which indicates further investigation and possible execution changes by the commander. By using the Sync Visualizer's unique combination of spatial and temporal axes in an integrated view, the commander can see critical mission relationships without having to mentally associate between separate displays.

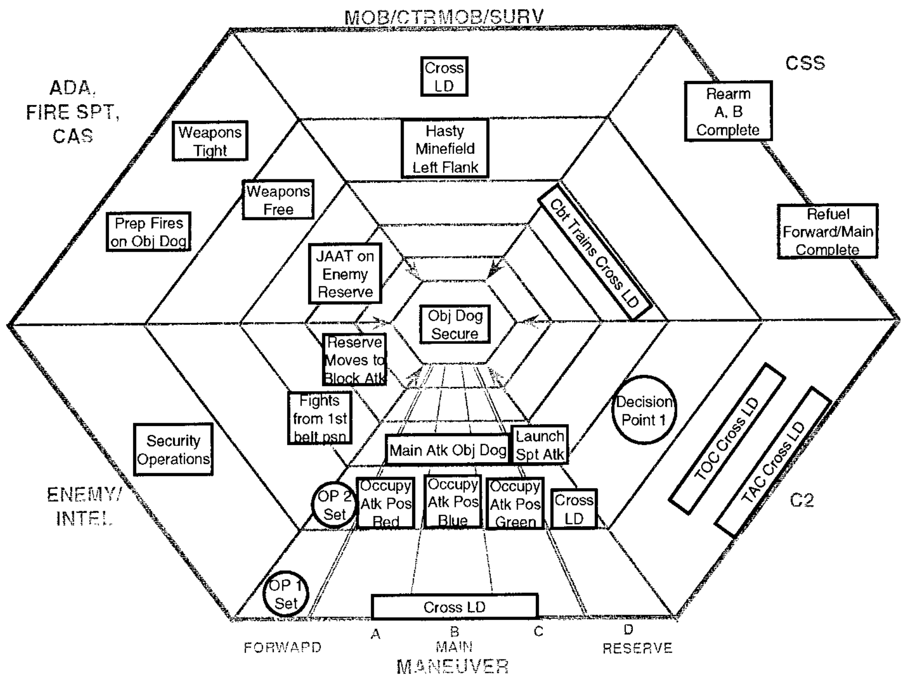

Figure 10. Populated synchronization array

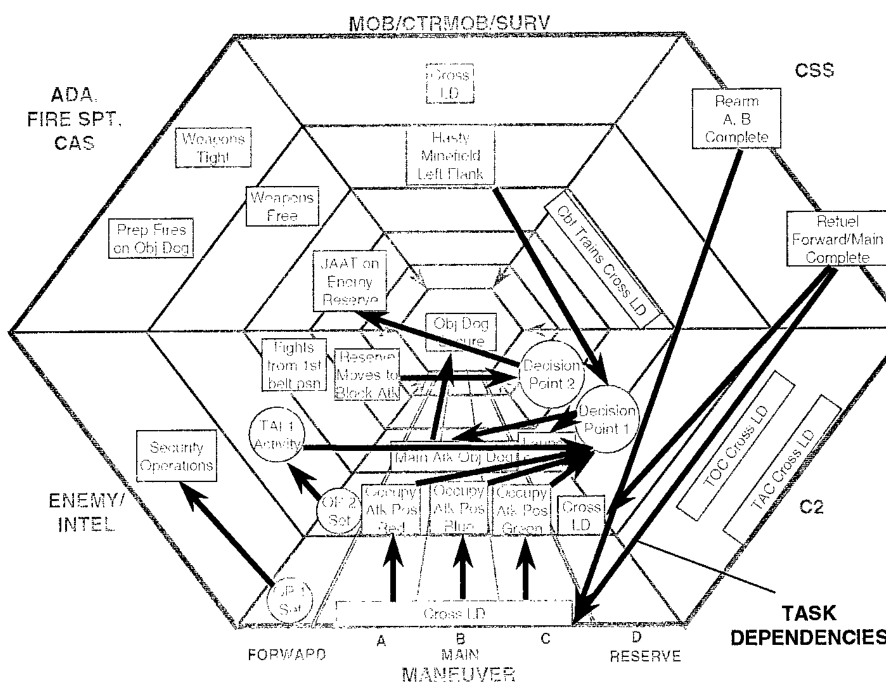

Figure 11. Highlighted task dependencies between synchronization tasks

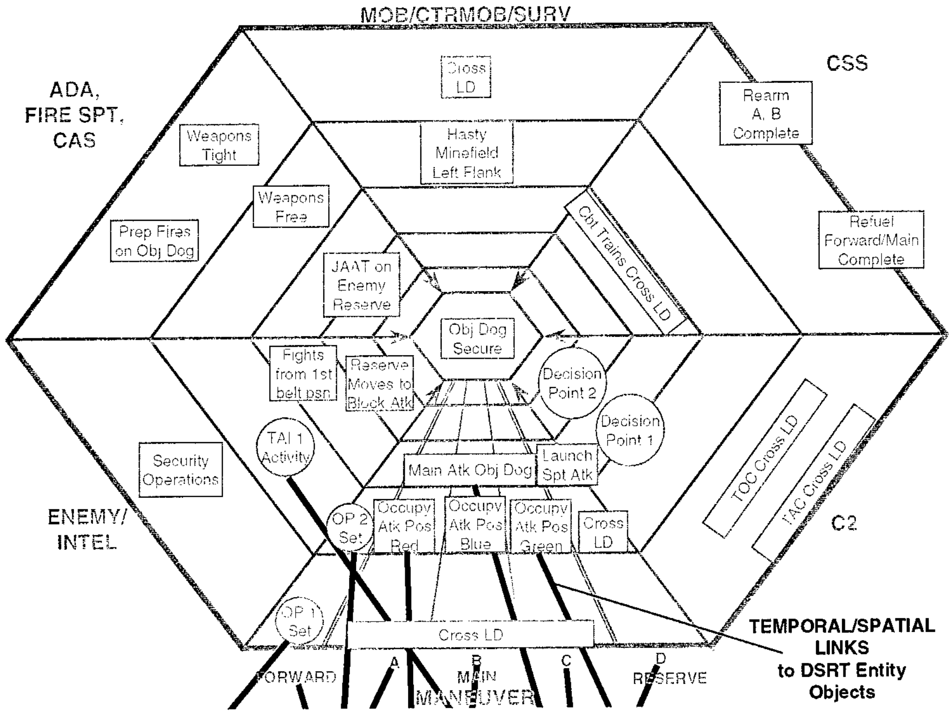

Figure 12. Highlighted links between temporal sync array and 3D spatial battlespace

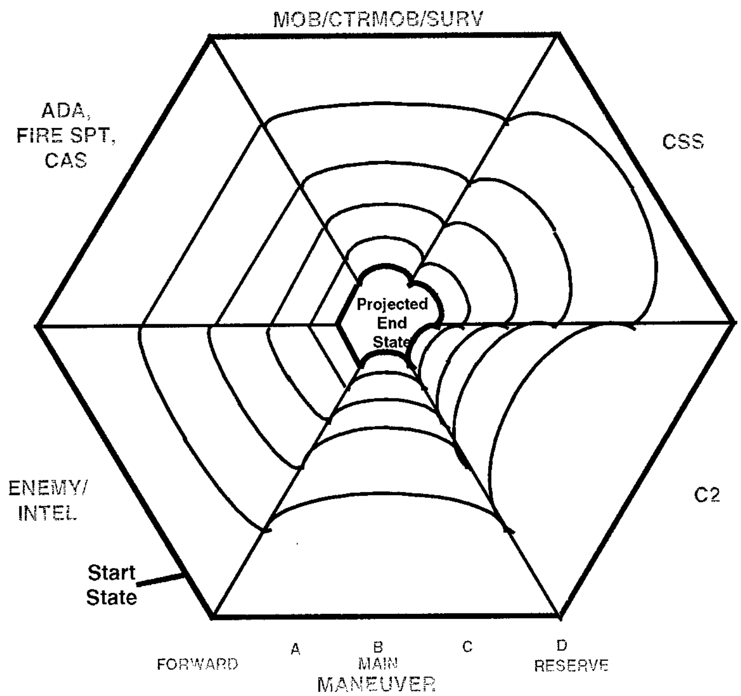

Figure 13. Synchronization array with curvature mapped to BOS mission status

In addition to information portrayed in the synchronization array, classes of DSRTs portray mission entities in the surrounding 3D battlespace. These DSRTs can take the form of objects, surfaces and volumes. Intuitive DSRT sensory cues such as shape, color, shading, texture,

transparency, sound and animation are used to represent battlespace attributes. Figures of DSRT unit objects and surfaces have already been discussed and examples shown in the Phase I results section. These DSRTs represent spatial battlespace mission locations and can be linked to associated icon representations in the synchronization array.

The system architecture for the DSRT system for battlespace visualization is envisioned to be a modular collection of processes which can be embedded into the BPV effort at CECOM during Phase II work. Figure 14 illustrates proposed key system architecture components from the DSRT system, and interface "hooks" to other proposed key components of the BPV effort.

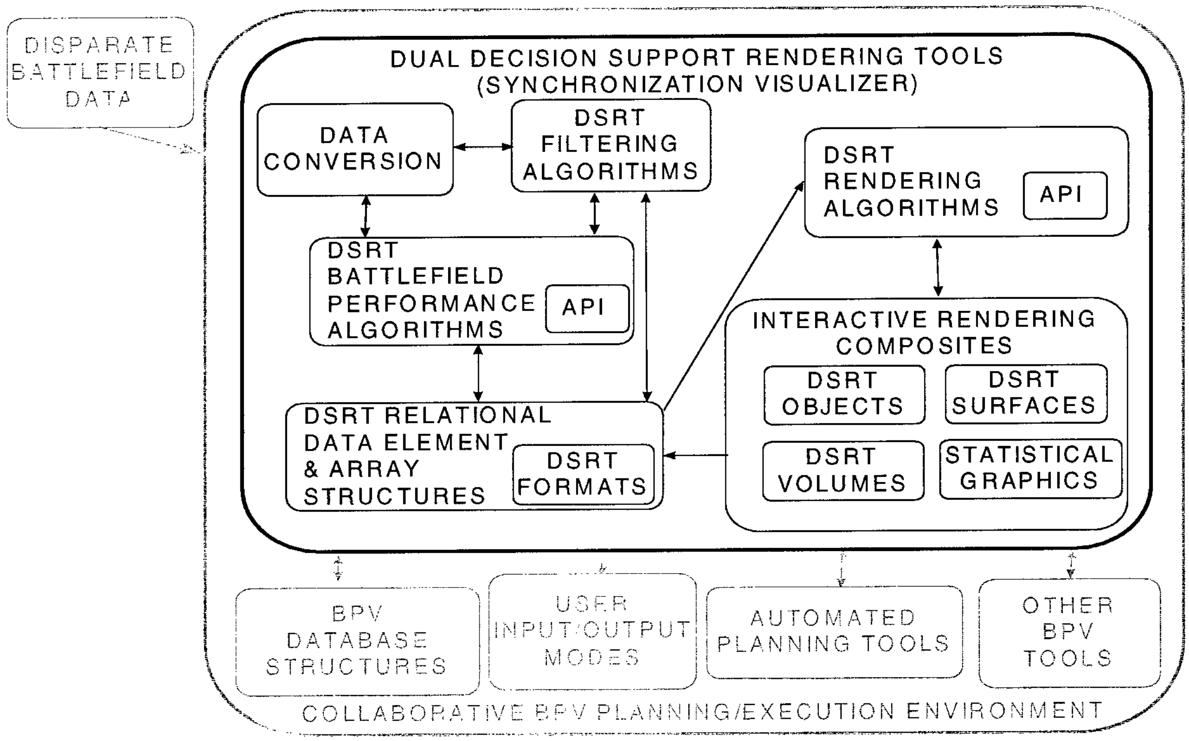

Figure 14. Synchronization Visualizer overall system architecture

In this system architecture, disparate battlespace data is input into the BPV collaborative environment which includes users, automated planning tools, and other software tools. This data is initially stored in BPV database structures. The DSRT system, in turn, accesses BPV data and conducts necessary data conversion and filtering processes. Battlespace performance algorithms, such as aggregate combat potential arrays are then calculated in near real-time by algorithms and this performance data is stored in DSRT relational data element and array structures. Other relational data is directly input from the filtering process. Decision support data can then be converted into DSRT rendered composites containing objects, surfaces, volumes, and statistical graphics, which are dynamically superimposed in the BPV 3D rendering environment. DSRT classes contain data manipulation interfaces to interactively explore dynamic and static doctrinal performance measures to support battlespace command and control. To show the feasibility of this approach, Figure 15 shows the current Phase I integration of DSRT composite intervisibility surfaces in Win BPV. The 'renderPlot' and 'threeDFrame' are existing WinBPV functions developed at CECOM. The highlighted functions

which start with 'dsrt…' show embedded DUAL functions which enable DSRT data conversion, battlefield performance algorithms, and rendering algorithms in order to demonstrate DSRT surface functionality. APIs can then be developed when necessary in Phase II based on DUAL's embedded functions which are integrated with CECOM's current prototype BPV software.

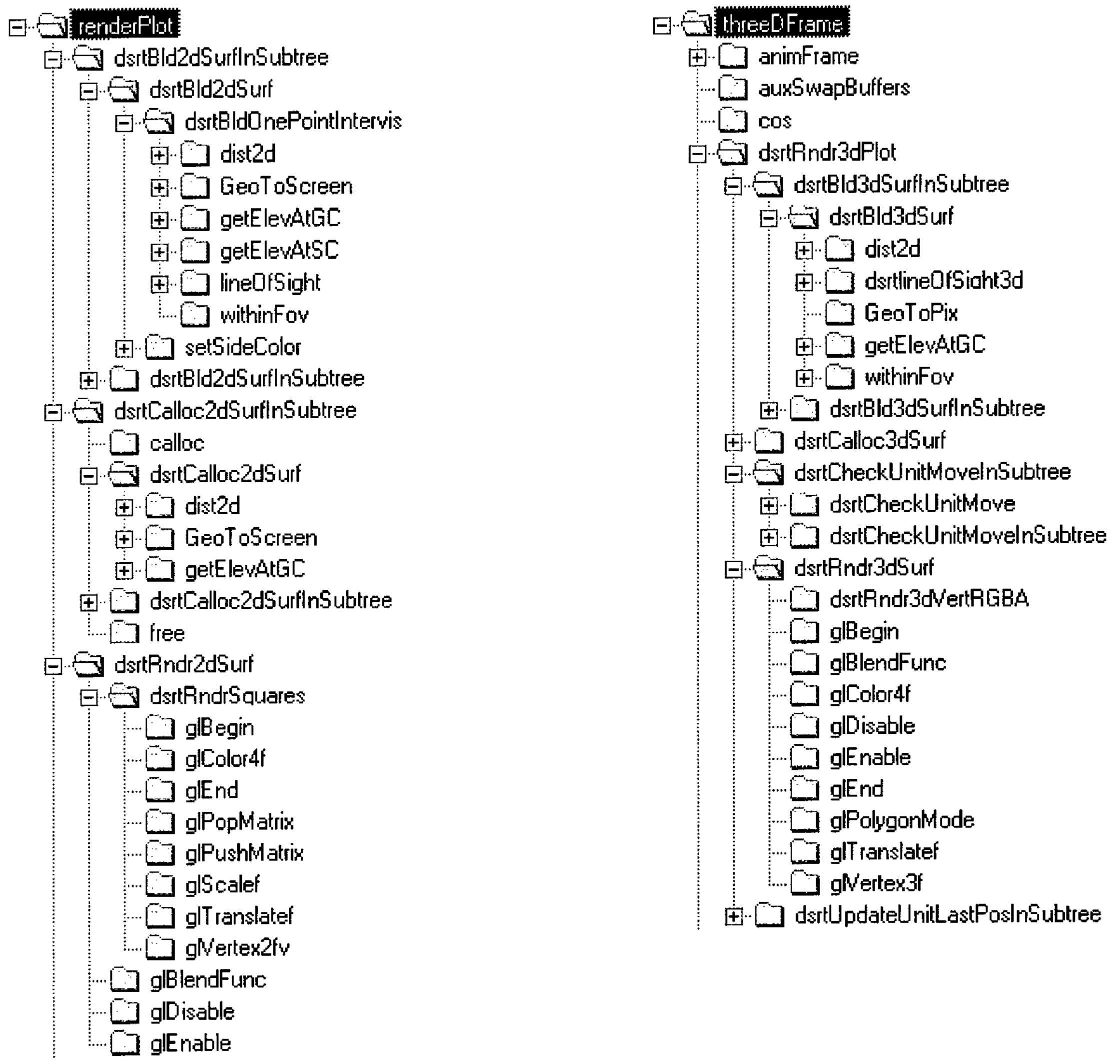

Figure 14. Phase I Integration of DSRT Composite Intervisibility Surface in Win BPV

Proposed hardware configurations for the Synch Visualizer prototype will allow both non-immersive and immersive interaction. Non-immersive interface peripherals include a standard mouse and monitor display, as well as the addition of Crystal Eyes Stereo Glasses to aid in 3D depth perception. The immersive interface will require a lightweight head mounted display and headtracking system as well as a Spaceball 3003 navigation peripheral to facilitate navigation and interaction in the 3D battlespace environment. It is proposed to procure the immersive peripherals approximately half way through the project duration due to lighter, better resolution displays becoming available then. It is also proposed to procure a Windows NT 3D laptop at this time with enough graphics capability for real-time 3D navigation in BPV.

APPENDIX A

Contribution to:

The Future of Battlefield Visualization White Paper

The Command Challenge of Understanding the Battlefield Image

A key aspect of the battlefield planning and execution process is the comprehension and synthesis of relevant battlefield information into a composite mental model or image. This is essential in order for the commander to make real-time informed decisions. Information concerning the battlespace domain can be viewed in terms of the mission, enemy, terrain and weather, friendly troops, time and space (METT-T). Battlespace awareness involves an information quest for certainty about these METT-T factors including; the state and intentions of the enemy's forces; environmental factors; and the state, intentions, and activities of one's own forces (van Creveld, 1985). An ever increasing flow of digital information including imagery, mission orders and graphics, entity locations, friendly and enemy status reports, environmental conditions, and forecasts of enemy intentions is available to commanders to increase their certainty of forming and conveying accurate battlespace mental images. However, due to the overwhelming complexity of such information, the commander and staff are prone to misinterpret the battlespace image, focus on the wrong level of detail, misunderstand information certainties, and not effectively comprehend information critical to mission decisions (Kahan, Worley, and Stasz, 1989).

The overwhelming volume and complexity of battlespace information is a result of advances in military sensor and communications technology. These advances are enabling real-time imagery, video, audio, graphical, and other digital data to flow from mounted and dismounted sensors, warfighters, and support entities to command centers. Once this raw digital data reaches command centers, the right levels of relevant mission information need to be derived and interactively visualized for timely decision support. This visualization includes the integration of both realistic and abstract battlespace information. Realistic information includes aerial imagery, terrain elevation and features, weather effects, and locations of actual deployed weapon systems. Abstract information includes mission orders, control graphics, weapons system capabilities, unit status, relationships between weapon systems, and doctrinal mission performance measures. Both realistic and abstract information complexity will continue to increase as battlespaces and other topographic domains evolve into Mirror Worlds (Gelernter, 1992). The Mirror World concept deals with software models starting to mimic reality, with oceans of system information pouring endlessly into synthetic information models.

Commanders are having increased difficulty in efficiently processing this complex battlefield information using conventional tools, which creates the need for technical innovation. Human information processing tasks include the mental decoding and synthesis of battlefield information. Conventional battlefield visualization tools featuring 2D displays are currently used for this mental processing. Typically, a topographic view of the battlespace is separate from multiple related windows filled with text and numeric mission data, creating dense visual clutter. Abstract mission information contained in 2D synchronization planning and execution matrices are portrayed separately from 2D or 3D topographic battlespace views. Problems with such 2D displays include limited dimensionality and limited amounts of information that can be portrayed. Limited dimensionality creates the need for multiple 2D representations that require the user to mentally integrate information across displays (Wickens, Todd, & Seidler, 1989). Also, the "flatland" of 2D displays limits the amount of information that can be represented in a display by only representing two planar dimensions. Tufte (1990) has stated that, "Escaping this flatland is the essential task of envisioning information, for all the interesting worlds...that we seek to understand are inevitably and happily multivariate in nature." Due to these current display limitations, there has been a pressing need to develop better data presentation techniques to support everyday tasks of exploration, understanding, and decision making (Robertson, Card,

and Mackinlay, 1993). This need for innovative battlefield visualization tools also applies to a critical unsolved graphic design challenge in future Mirror Worlds: how to represent the state of complex dynamic systems that will change as you watch. The increased richness and dimensionality that 3D rendering capabilities bring to scene and object representations creates possibilities for addressing such information visualization challenges.

Computer graphics technology has advanced in the area of real-time 3D and imagery rendering. This has resulted in the development of 3D rendering tools including 3D libraries, higher level 3D application programming interfaces (APIs) and 3D toolkits. An industry standard low level 3D API is OpenGL, which is supported on Unix and PC platforms. Higher level 3D APIs are being developed in universities and industry to support topographic, data, and other visualization tasks. Examples of relevant 3D API development work is the Virtual Geographic Information System (VGIS) project at Georgia Institute of Technology and the Selective Dynamic Manipulation (SDM) project at Carnegie Mellon University. 3D toolkits are also available which facilitate the creation of cross platform 3D virtual environments. Examples are Sense8's WorldToolKit and Division's dVISE. Using this technology, some 3D battlespace information displays have already been prototyped.

A problem with current prototyped 3D information tools and displays is that they do not currently make effective use of the rich set of attributes associated with 3D rendering. This has been evident in battlespace situation displays associated with 3D geographic rendering environments. Examples of such battlefield displays are 2D unit symbol polygons with hyperlinks to other 2D information windows; 2D synchronization matrices; and 3D opaque, colored volumes with invariant geometry. In these current prototypes, designers seem to be focusing on mapping information to 3D display attributes that are familiar or aesthetically pleasing, such as 2D billboards or simple shapes, as opposed to 3D attributes that best support information tasks. There is very limited direct interaction and manipulation of the 3D display; instead, the user inputs selections and text in separate 2D windows.

The current generation of 2D tools and prototyped 3D tools have not currently addressed battlespace information comprehension problems. The current situation is not much different than a decade ago:

> Taken as a whole, present-day military forces, for all the imposing array of electronic gadgetry at their disposal, give no evidence whatsoever of being one whit more capable of dealing with the information needed for the command process than were their predecessors a century or even a millennium ago (van Creveld, 1985).

One reason for this continuing problem has been shortcomings in the development of scientifically-based 3D visualization solutions for critical battlespace information needs. Developers have lacked understanding of information needs at various echelon levels and expertise in effective 3D techniques to address these needs.

Theoretically and experimentally-based 3D rendering and user interaction techniques need to be applied to unleash the information productivity that 3D rendering technology offers. A technology-driven approach has constrained effective development of 3D information visualization tools due to heavy reliance on existing 2D display techniques and limited use of the increased dimensionality of 3D rendering attributes. Now, the advent of theoretically and experimentally-based 3D visualization tools presents the opportunity to significantly enhance human information processing of the complex, dynamic battlespace commercial domain.

Experimental research is now emerging which provide indications that 3D visualization tools can enhance battlefield visualization. One research direction has explored the use of perceptually emergent features in 3D complex system displays. Emergent features can be thought of as visual attributes of a display which "pop out" of the display for easy detection and decoding. These features result from combinations of elementary display components, which means they can represent relationships between multiple system categories or can represent overall system status. This is especially useful when real-time synthesis of information is required to assess the current state of a dynamically changing complex system, such as the battlefield image. Examples of 3D emergent features are gaps and curvatures in 3D display objects. Experimental results have shown improvements in information tasks when using 3D emergent feature displays over conventional 2D bar graph displays (Dryer, 1996). In particular, a display using 3D gap/intersection features to represent system status did live up to the promise of providing significant improvement in graphical information processing over an accepted current generation 2D bar graph display. Another research effort developed integrated displays representing the composite intervisibility and combat potential of an entire unit's combat systems (Fernan & Dryer, 1994). By viewing an overall display surface, concentrations and gaps in unit combat power are visible. Such 3D display techniques as those mentioned above are increasingly needed to assist commanders in quickly understanding dynamic battlefield images.

Since there is emerging evidence that 3D information displays can enhance information processing task, applied research is now beginning to improve the display of abstract METT-T information currently represented on 2D planning and execution matrices. Such matrices help organize tactical unit missions in terms of spatial and temporal synchronization, as well as organizing force structures and command relationships. However, this abstract mission information is not currently integrated with realistic information including natural and man-made terrain features. By using real-time 3D rendering technology, many aspects of abstract 2D planning and execution matrices can be portrayed directly on familiar 3D terrain representations. Through use of increased dimensionality and more visual attributes available with this technology, the spatial, temporal, and organizational relationships involved in tactical missions can be more directly portrayed and compared. This, in turn, can increase the accuracy and latency involved in decoding and synthesizing dynamic battlefield images.

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APPENDIX B

Concept Experimentation Program Resume Sheet

Battlefield Virtual Information Tools For Brigade and Below (BVITB2)

CONCEPT EXPERIMENTATION PROGRAM
RESUME SHEET

Type Submission:
NEW_X_ REVISED___
Date: 1 MAY 98
ATZK-MW DSN 464-7435

EXPERIMENT TITLE: Battlefield Virtual Information Tools for Brigade and Below (BVITB2)

TYPE: CEP

CATEGORY: CEP Experiment

AUTHORITY: TRADOC

SPONSOR: MMBL, USAARMC

INSTALLATION: MMBL, Fort Knox

ORGANIZATION: MMBL

UNIT: USAARMC

LOCATION: Fort Knox, KY

EXPERIMENT DATES: MAR 99

AMMO: NO FLYING HOURS: NO INST: NO TGT: NO SIM: NO

TOTAL DIRECT EXPERIMENTATION COST ESTIMATES: $207 K

APPN: RDT&E

FUTURE OPERATIONAL CAPABILITY(S) LINKAGE:
The following Mounted Maneuver Battlespace Lab (MMBL) Future Operational Capabilities are either fully or partially supported by this CEP in the linkage capacity specified.

1. MMB 97-017: Mounted Command and Control on the Move

CEP Linkage Description: The CEP proposes a method to maximize the mounted force commander's ability to synchronize operations, be constantly in communication with key subordinates, and to establish, control and alter tempo as required to conduct decisive operations. This will be accomplished using robust, long-range, seamless, ground systems/subsystems while both the commander and the commanded force are on the move. It can be accomplished during and immediately after deployment. Commanders will have the capability to maintain robust situational awareness, and rapidly send and receive intelligence information, and plans and orders in real-time and

on demand. Commanders and staffs will operate out of highly survivable, mobile, and stealthy ground command posts that function on the move. Communications and situational awareness must be maintained while commanders are transferring from one vehicle to another and while they are dismounted. Commanders will be able to maintain the same awareness of the situation and the same contact with subordinates when they leave their vehicles and are dismounted or riding in other vehicles. Battle command systems will be flexible enough to be integrated into mounted platforms and mobile command posts. Communications systems will be secure, reliable, compatible, and use automated processing. Communication and automation will be interoperable between joint and coalition forces for which spoken human-machine dialogue will be essential to obtaining accurate and error free interpretations without delay.

2. MMB 97-018: Common Picture, Decision Support, Mission Planning and Rehearsal During Decisive Operations

CEP Linkage Description: This system will be capable of rapidly sending and receiving text, in realtime and on demand from ground systems. This will provide units a mission planning and management system capable of pre-mission planning, COA (Course of Action) development, data loading, and mission rehearsal.

3. MMB 97-019: Mounted Forces Situational Awareness

CEP Linkage Description: This CEP will provide mounted systems robust and overmatching situational awareness (the ability to have accurate and real-time information of friendly, enemy, neutral, and noncombatant locations; a common, relevant picture of the battlefield scaled to specific level of interest and special needs) to enhance survivability, provide command and control, gain maneuver dominance, dictate battle tempo and conduct decisive operations in a non-linear, expanded battlespace. This will allow capability for soldiers and commanders to be provided the information from sensors necessary for them to visualize the entire battlespace as it exists in real time. Commanders will be able to rapidly access, update, retrieve, display, and transfer terrain and weather data, and manmade obstacles/barriers, and contamination hazards information in support of intelligence preparation of the battlefield to higher, lower, adjacent, joint and allied forces. This includes the capability to transmit/receive multi-discipline predictive intelligence and warning text report data.

4. MMB 97-007, CEP Linkage Description: The added functionality provided by this CEP includes the capability to restrict the enemy's mobility, control his battle tempo, and to seize and maintain maneuver dominance.

5. MMB: 97-012, Maneuver Force Protection

CEP Linkage Description: This proposes increased capability to conduct effective security operations.

6. MMB 97-013, NBC Warning to Mounted Forces

CEP Linkage Description: This CEP proposes capability to provide early warning to individual soldiers and ground mounted platforms

7. MMB 97-015, Prevention of Fratricide

CEP Linkage Description: Increased capability to positively identify potential targets at the maximum ranges of weapons systems. Capability to track the locations of all friendly elements plus an in-sight, pre-engagement, positive identification of potential targets for both direct-fire and indirect-fire weapons platforms.

8. MMB 97-020: Simulation

CEP Linkage Description: This proposed added capability permits units at all echelons and at different locations (garrison and deployed) to train and fight together through a combination of virtual, constructive and live simulations in a mission planning/rehearsal system. This simulation capability span the full range of military operations and be embedded in equipment. This capability supports both the training of the mounted force and the ability to conduct decisive operations. The simulations will be seamless, distributed, and interactive, provide aggregation and degradation of forces, and include advancements in methods and models for determining fidelity requirements. The simulation technology will possess the capability to conduct simultaneously interactive training from the individual system to the brigade level across battlefield operating systems. The training simulation system will use spoken human-machine dialogue and will allow the user to construct his own environment as required, and without the aid of computer programmers. This will allow the user to make rapid changes in the training and combat rehearsal environment as required by changing needs.

CEP DIRECTION FACTOR:

DA-Directed/ongoing	1	___
TRADOC-directed	2	___
Define operational concept	3	_X_
Refine materiel requirement/ Evaluate DTLO	4	___

SPONSOR PRIORITY: 1_X_ 2___ 3___ 4___ 5___ 6___ Other__

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PURPOSE/OBJECTIVE/DESCRIPTION:

PURPOSE: To evaluate potential improvements in real-time interactive retrieval, comprehension, synthesis, and dissemination of current and future projected battlefield information, including Commander's Critical Information Requirements (CCIR), using advanced information visualization concepts embedded in next generation Battlefield Virtual Information Tools for tactical command and control.

OBJECTIVE: To demonstrate enhancements in the future operational capability of the commander to use 3D interactive technology to quickly understand his tactical situation from multiple digital sources and communicate mission intentions to other battlefield entities. The user interacts with a realistic virtual 3D terrain-based representation of the battlefield containing dynamic interactive object and surface graphical 'tools' allowing portrayal of critical mission information and creation of graphical notation to communicate mission intentions. The objective of this resume sheet is to obtain funding for concept exploration, demonstration hardware purchase and fabrication, conducting preliminary checkout testing, test planning, user training, test execution, and preparation of a final report documenting the results.

DESCRIPTION: The concept of using interactive virtual information tools, which are embedded in 3D virtual environment, was briefed to the armored community at the MMBL, Fort Knox and received great interest. Currently, an interactive 3D display system called the Synchronization Visualizer is being developed as a synchronization planning and execution interface to the U.S. Army Communication-Electronics Command (CECOM's) Battlefield Planning and Visualization (BPV) System. This CECOM development effort is using decision support rendering tool (DSRT) technology developed at Dual, Incorporated (DUAL) to enhance interaction with a current generation synchronization matrix. This CEP proposes to expand the development of 3D information displays into next generation virtual information tools to be used by the commander to quickly understand his tactical situation from multiple digital sources and communicate mission intentions to other battlefield entities in near real-time. These tools will assist in the interaction and comprehension of the overwhelming volume and complexity of battlespace information resulting from advances in military sensor and communications technology. These advances are enabling real-time imagery, video, audio, graphical, and other digital data to flow from mounted and dismounted sensors, warfighters, and support entities to command centers. Once this raw digital data reaches command centers, the right levels of relevant mission information need to be derived and interactively visualized for timely decision support. The proposed Battlefield Virtual Information Tools for Brigade and Below (BVITB2) effort develops an interactive visualization system representing both realistic and abstract battlespace information. Realistic information includes aerial imagery, terrain elevation and features, weather effects, and locations of actual deployed weapon systems. Abstract information includes mission orders, control graphics, weapons system capabilities, unit status, relationships between weapon systems, and doctrinal mission performance measures. By mapping multiple critical information requirements onto 3D 'emergent feature' object and surface rendering attributes, such as shape, color, texture, and transparency, the commander better perceives and comprehends the current battlefield situation. Of particular note is the system's ability to represent doctrinal performance, including the reinforcing effects which are discussed in FM 100-5. In addition, the BVITB2 system contains graphical creation and dissemination tools for the commander to communicate future mission intentions through 2D and 3D graphical notations in the same virtual environment. The overall BVITB2 concept is to provide a 3D battlefield information workspace for improved command and control mission performance at the brigade and below level.

EXPERIMENT CONCEPT: For the demonstration of this added capability, the contractor will support demonstrations to the armored community and testing at the Mounted Maneuver Battlespace Laboratory (MMBL) Testbed, Ft. Knox. The contractor will fabricate and support testing using an interactive virtual environment hardware and software system using a Battlefield Virtual Information Tools for Brigade and Below (BVITB2)

prototype system. This system potentially includes an enhanced version of the CECOM BPV System. Testers will observe and collect test results evaluating added value of capability, scope, and performance throughout the drill

SCOPE: The accuracy and latency of users in the human information processing of real-time battlefield information in various brigade and below scenario situations, and the ability for improved creation and dissemination of mission intentions will be evaluated to determine the improvements in operational awareness and effectiveness of the following:

1) Detection and Comprehension of Commander's Critical Information Requirements (CCIR):
Assesses the user's ability to retrieve and comprehend specific information elements relevant to the mission.

2) Enhancement in Human Synthesis of the Overall Battlefield Image:
Assessing the user's ability to integrate multiple information elements into an accurate overall assessment of mission status.

3) Communicating Commander's Mission Intentions:
Explores the expanded use of creating and disseminating mission intentions using graphical notations directly in a 3D virtual environment.

CONCEPT OF EMPLOYMENT: The quick and accurate comprehension and synthesis of current and future Commander's Critical Information Requirements (CCIR), including priority intelligence requirements (PIR)-information about the enemy; essential elements of friendly information (EEFI)-information needed to protect friendly forces from the enemy's information-gathering systems; and friendly forces information requirements (FFIR)-information about the capabilities of adjacent units is possible from this Battlefield Virtual Information Tools System. In addition, the creation and dissemination of commander's mission intentions in more concise graphical formats through use of graphical annotation tools offers an enhanced ability to both perceive and communicate mission information directly in a 3D terrain-based interactive environment.

IMPACTS: The environmental and energy impacts of this system are negligible.

POINTS OF CONTACT (POCs):

LN	AGENCY	LOCATION	OFFICE SYMBOL	TELEPHONE
	USAARMC,MMBL	Fort Knox, KY 40121	ATZK-MW	464-7435
	DUAL, Inc	Lake Mary, FL	Research and Technology	(407) 333-8880

SECTION I
EXPERIMENT RESOURCE REQUIREMENTS

1. EXPERIMENT DIRECTORATE: The test directorate for this CEP will be assembled from members of MMBL and Armor Center, Fort Knox using test personnel and facilities from Ft Knox, KY. The personnel requirements below is a suggested augmentation to support this CEP.

A. Personnel Requirements:

LN	POSITION	GRADE	MOS	QTY	INCLUDE DATES	SOURCE
A001	Test Officer	03/GS-11/12		1	T-180 to T+30	MMBL
A002	Data Collector	03/GS-10/11		1	T-30 to T+30	TECO
A003	Data Reducer	03/GS-11		1	T to T+90	MMBL

B. Equipment Requirements:

LN	TYPE	QTY	INCLUDE DATES	SOURCE
B001	SGI Octane Computer	1	TBD	MMBL
B002	"VIEW" HMD	1	TBD	MMBL

2. PLAYER PARTICIPANTS: N/A

A. Personnel Requirements:

(1) Individual Requirements: TBD

LN	Position	Grade	MOS	Qty	Incl Dates	Source

(2) Unit/Element Requirements: TBD

B. Equipment Requirements: TBD

3. ITEM(S) TO BE EXPERIMENTED ON:

A. Experiment Items:

LN	DESCRIPTION	QTY	INCLUDE DATES	SOURCE
F001	TBD			

B. Support Requirements: TBD

4. DATA COLLECTION/ADP SUPPORT: TBD

A. Data Collection/Processing System:

LN	ADP Equipment/Supplies	Qty	Incl Dates	Source

B. ADP Facility Support: N/A

C. Contractor or Other Government Agencies: N/A

5. AMMUNITION, PYROTECHNICS, AND MISSILES: N/A

A. Ammunition and Pyrotechnics: N/A

B. Missiles: N/A

6. PETROLEUM, OILS, AND LUBRICANTS (POL) SUPPLIES: N/A

7. INSTRUMENTATION: N/A

A. Equipment: N/A

B. Contractor or Other Government Agencies: N/A

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8. EXPERIMENT FACILITIES/INSTALLATION SUPPORT:

A. Experiment Facilities Range Support: N/A

B. Communication/Engineering Support:

LN	DESCRIPTION	QTY	INCLUDE DATES	SOURCE
Q0001	TBD			

C. Installation Support:

LN	DESCRIPTION	QTY	INCLUDE DATES	SOURCE
R001	TBD			

D. Other Support: TBD

9. SIMULATORS/TARGETS: N/A

A. Simulators:

B. Targets:

10. FLYING HOUR SUPPORT: N/A

SECTION V
OPERATIONAL ISSUES AND CRITERIA

Experiment Number: 99-CEP-1705

Experiment Title: Battlefield Virtual Information Tools for Brigade and Below (BVITB2)

Experiment Type: CEP DCE

1.0 ISSUE. Will BVITB2 information tools enhance battlefield situational awareness through improved human information processing of critical battlefield information?

1.2 CRITERIA. Qualitative and quantitative measures are collected as part of MMBL experimentation. The feasibility of embedding quantitative assessment probes into BVITB2 will be investigated. Measures will focus on the ability to retrieve critical battlefield information, retain individual information elements and synthesize battlefield information into overall mission status.

1.3 SCOPE. Comparisons are conducted between current generation 2D information displays and next generation 3D BVITB2 information tools.

1.4 RATIONALE. Theoretical and experimental research related to graphical information processing shows indications that properly designed 3D graphical information displays are significantly more effective than current generation 2D graphical information displays for accurately and latency. Proper design of such 3D displays includes incorporation of dynamic emergent feature attributes (such as shape curvature) in the display and mapping critical information to such emergent features.

2.0 ISSUE. Will BVITB2 information tools enhance the user's ability to create and disseminate future tactical mission intentions?

2.2 CRITERIA. Qualitative user assessments concerning ease of use of graphical mission notation tools is collected as part of MMBL experimentation. User assessments and feedback concerning the intuitive design and enhancement of the graphical notation 'language' is also collected.

2.3 SCOPE. Comparisons are conducted between current generation tools for communicating mission intentions (including OPORD and FRAGORD methods) and next generation BVIT graphical notation tools.

2.4 RATIONALE. The U.S. Army tactical planning process currently relies on some 2D graphical notation (e.g., unit and mission symbology)

for creation and dissemination of mission intentions. There is great potential and some theoretical basis for enhancing this current symbology system so that less textual and linguistic information is required. Emerging graphics and interface technology can enable such graphical mission orders to be quickly created and distributed for future near real-time mission planning/execution requirements.